ORDNANCE MANAGEMENT ENGINEERING TRAINING AGENCY
WORK PLANNING AND CONTROL COURSE
SUBJECT 12
MATERIAL MANAGEMENT

Time:
3/4 Day

Equipment:
C - 2" x 2" slide projector
C - Slides: Subject 12

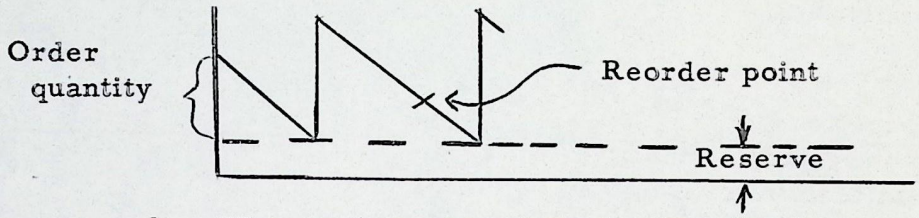
Topics:
1. Introduction
2. Economic order quantity
3. Classification of inventory by dollar usage.
4. Modifications of approach for fixed storage capacity or limited facilities for order processing
5. Modifications for quantity discount and variable usage.
6. Introduction to reorder point determination.
7. Scientific reorder point determination.
8. Sequence of events surrounding reorder point and order quantity found in many activities.
9. Making inventory studies.
10. Project assignment.

1. INTRODUCTION

A. Definition: The scientific determination of min., max. points and order quantities.
   1. To be discussed in some detail.
   2. Realize that many students not in a position to effect policy, but some may be and others may be some day.
   3. A fertile field for high savings by reducing following costs:
      a. Investment of capital
      b. Obsolescence
      c. Storage
   4. Getting a great deal of attention lately
      a. Oversupply of cars
      b. G.M. has 1-1/2 billion tied up in inventory.
      c. "Inventory Recession"
   5. Classical approach has been "Rate of Turnover"
      a. Increased rate not necessarily an improvement in spite of common thought that it is.

b. Must consider each item in terms of all contributing costs.

B. Graphic picture of subject:



1. What is the economic order quantity?
2. When should stock be reordered?
3. Amount you order can be determined independently of the reorder point, but not the reverse.

C. References:
1. T. M. Whitten, "Theory of Inventory Management"
   a. Very mathematical
   b. In O. M. E. T. A. library
2. W. Evert Welch, "Scientific Inventory Control"

2. ECONOMIC ORDER QUANTITY:

A. For many years a problem analyzed by persons interested in scientific management.
In 1900 one book published over 60 formula.

B. Extreme views:
1. Produce all at once - limit set-up; shop orientated solution.
2. Produce very small lots limit storage cost.
3. Which approach is right? Neither. Must balance costs.

C. The variable costs of inventory
1. Those costs which vary with the size of the order quantity.
2. Also discussed as incremental costs.
3. Made up of two principle factors:
   a. The costs that vary with the number of times the order is produced (set-up or procurement costs)
   b. The costs that vary with the number of pieces placed in inventory (Storage or carrying charge)

4. Same factors apply whether we are considering items which are purchased or produced.
5. The concept of varying costs as effected by order rate and inventory is not as simple as might appear.
   a. Changes up to about 10% would have little effect.
   b. Changes of 50% or so would cause complete reorganization and probably necessitate construction.
   c. Each situation must be evaluated on the existing conditions but it is frequently found that in our basic analysis we should consider the varying costs in terms of the effect of a change in order rate or inventory of approximately 25%.

D. Procurement or set-up costs:
   1. Have class list departments in which these costs will be found. List should include:
      a. Purchasing
      b. Inspection
      c. Accounting
      d. Receiving
      e. Stores
      f. Auditing
      g. Mail Handling
      h. Trucking
      i. Production (Where we are considering parts made in the plant)

   2. Set-up costs:
      a. Set-up time
      b. Job change time
      c. Instruction and operation checking
      d. Scrap
      e. Training or building up speed on particular operation.
   3. Paper and material costs
   4. Production Control costs:
      a. Paper preparation
      b. Scheduling
      c. Expediting and follow-up
   5. Generally should include salaries of non-supervisory personnel, but not those of supervisory personnel.

6. Usually better to estimate than try to apply current accounting data.
7. These costs increase as order quantity decreases i. e. order rate increases.

E. Carrying charges
1. Costs which vary with the size of the inventory.
   a. Usually based on average inventory which is 1/2 order quantity
   b. Expressed as a % of average inventory.
2. Ask enrollees to indicate factors which they feel should be included in this determination: List should contain the following:
   a. Storage space
   b. Maintaining material and deterioration
   c. Maintaining stock records
      (1) Posting
      (2) Annual Inventory
   d. Insurance (Not in gov't.)
   e. Obsolescence
   f. Interest
   g. Taxes (Not in gov't.)
   h. Repackaging and rehandling
   i. Risk of destruction by the enemy
3. AMA lists 256 factors which may be considered.
4. Comments on most important factors:
   a. Interest - government 3-1/4% - bonds; What we have to pay for more money, not necessarily current rate.
   b. Insurance and Taxes - straightforward accounting figures.
   c. Obsolescence and depreciation - an estimate, usually for classes of items.
   d. Storage - again items must be classed if you have great difference in size or storage conditions. Some people compute the storage cost separately based on square feet and whether or not space should be determined on maximum or average inventory. In practice this is not a determining factor so we will neglect it.
5. These costs decrease as order quantity decreases, i. e. order rate increases.

6. The industrial average for this charge is between 15 and 25%.

F. Another consideration in the variable costs of inventory is that as the order quantity decreases or the order rate increases, the probability of a "stock-out" (running out of material before the next order is received) increases. For this reason, we usually estimate procurement costs on the high side.

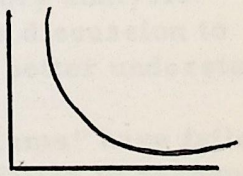
G. The goal of inventory management is to determine an order quantity such that the total variable cost of procurement and carrying inventory is a minimum. Give the enrollees the following information and have them determine an order quantity in terms of months supply which will achieve a minimum total yearly cost.

1. Given:
   a. Procurement cost - $10
   b. Monthly usage - $100
   c. Carrying charge - 20% of average yearly inventory.
2. Ask class for estimates of how many months supply should be ordered each time.
3. Put table on board and fill in:

Months Supply	1/2	1	2	3	4	6	12
Yearly procurement cost							
Average inventory*							
Carrying charge/year							
Total cost							

*100 Aver. = $50/Mo. or 1 year

0



4. Draw curve
5. Actual mathematical solution gives 3.46 mo. supply at cost of $68 as best solution.

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H. Formula development:

1. Wouldn't want to go through such a series of calculations every time we wanted to determine order quantity so will put into a formula.
2. Illustrate the variable and total costs graphically.
   a. Ask enrollees if they recognize this as a problem similar to that discussed in process planning - break-even point determination
   b. State that we will establish a formula which will give us an order quantity in terms of months supply such that the carrying costs and procurement costs are exactly equal.
3. Definitions:
   a. N - Number of months supply to be ordered at one time (economic order quantity.)
   b. M - Monthly usage - at $ cost
   c. P - Procurement cost - $
   d. I - Inventory carrying charge per year in decimals
4. If order 3 months supply at one time, order 4 times per year so 12/N equals number of order/year. Thus 12/N x P equals total yearly procurement cost.
5. Carrying cost:
   a. Average inventory equals N/2 x M (Average months supply in inventory times monthly usage.)
   b. Carrying cost equals N/2 x M x I.
6. Solve for break-even point:

$$N/2 \times M \times I = 12/N \times P$$

$$N^2 = \frac{24P}{MI}$$

$$N = \sqrt{\frac{24P}{MI}}$$

7. Apply formula to previous example as proof +
   a. For previous problem got an order quantity of between 3 and 4 months supply.
   b. $N = \sqrt{\frac{24P}{MI}}$

$$N = \sqrt{\frac{24 \times 10}{100 \times .2}} = \sqrt{12} = 3.46 \text{ months supply}$$

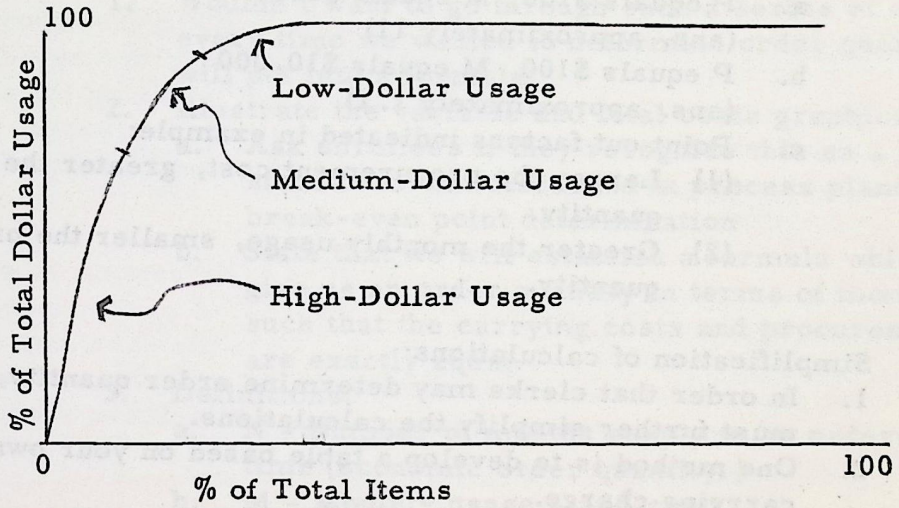
8. Formula practice:
   Have enrollees try following problems:
   a. P equals $100, M equals $100
      (ans. approximately 11)
   b. P equals $100, M equals $10,000
      (ans. approximately 1.1)
   c. Point out factors indicated in example:
      (1) Larger the procurement cost, greater the order quantity.
      (2) Greater the monthly usage, smaller the order quantity.

I. Simplification of calculations:
   1. In order that clerks may determine order quantity, we must further simplify the calculations.
   2. One method is to develop a table based on your own carrying charge.
   3. Can also develop nomographs to assist in this determination.
      a. Advantage - get continuous values.
      b. Disadvantage - likelihood of error.
      c. References:
         (1) Phil Carrol - How to chart Time Study Data
         (2) Welch - Scientific Inventory Control

3. CLASSIFICATION OF INVENTORY BY DOLLAR USAGE:

A. Introduction:
   1. The first step in any scientific inventory analysis.
      a. Have waited until this point in the discussion to introduce because enrollees will better understand the need for such a procedure.
      b. The reason many "scientific systems" have failed is because their designers have failed to recognize the need for treating various segments of the inventory in different ways.
   2. Basic concept is to divide the inventory into classes according to annual $ usage.
      a. Focus attention on the high dollar items.
      b. Not spend a disproportionate amount of time on determining order quantities for low dollar items.

B. Indicate distribution graphically



2. Indicate potential divisions for classification based on inflection in curve.
3. Common breakdown found in industry: 15% of the items create 85% of the total cost.
4. Figures from recent study of one company:
   a. Items with more than $2000 annual usage.
      (1) 6% of items carried in the inventory system.
      (2) 62% of annual inventory dollar volume.
   b. Items with between $500 and $2000 annual usage.
      (1) 15% of items carried in inventory system.
      (2) 23% of annual inventory dollar volume.
   c. Items with less than $500.00 annual usage.
      (1) 79% of items carried in inventory system.
      (2) 15% of annual inventory dollar volume.
5. Classifications such as this are known as ABC inventory classification.
   a. "A" represents high dollar items
   b. "B" represents medium dollar items
   c. "C" represents low dollar items
6. Sometimes add "D" classification and further divide when situation merits different consideration for low dollar items.

C. The classification indicates the frequency with which the factors going into the order quantity formula will be analyzed and order quantities recomputed.
   1. Want to work on a current basis on "A" items, but can afford to permit error in "C" items.
   2. Example of procedure used with breakdown indicated above:
      a. "A" items -
         (1) Check procurement cost and monthly usage for order period each time the item is ordered.
         (2) Order quantity to be approved by Chief of Inventory Control
      b. "B" items -
         (1) Check monthly usage for following six months for first order placed after Jan 1 and first order placed after June 1.
         (2) Order quantity for times indicated in (1) to be approved by chief of Inventory Control
         (3) Order quantity computed in (1) to be used for all subsequent orders in six month period. Approval of Chief of Inventory Control not required.
      c. "C" items -
         (1) Check usage bi-annually
         (2) Order quantity determined in (1) to be approved by chief of Inventory Control.
         (3) Purchase orders need not be approved by chief of Inventory Control.
   3. Sometimes add "D" classification for items usage such that one year's supply is always the order quantity.

4. MODIFICATIONS OF APPROACH FOR FIXED STORAGE CAPACITY OR LIMITED FACILITIES FOR ORDER PROCESSING:

A. Another reason for the failure of the so-called scientific approach to inventory control is that the designers of the system fail to recognize that certain physical facilities may be limited.
   1. Unsophisticated application of the formulas may come up with a large increase in average inventory and thus requirements for storage space which is not currently available.

2. Or such application may come up with a large increase in order frequency which the purchasing, receiving, warehousing and inventory control sections are not prepared to handle.
3. Should determine potential changes in storage requirements and/or change in order frequency by applying formulas to sample.
   a. If such changes are indicated, determine if facilities are available to handle them.
   b. Too frequently, this is not done and the resulting chaos results in scraping the entire system.
4. There are ways of minimizing costs with such restrictions.
   a. Will not give an absolute minimum cost solution as will the basic formulas, but will usually result in savings.
   b. Average inventory costs with these procedures should be compared with those in "ideal situation" and potential savings indicated to management.

B. Formula with Order Size and Storage Restrictions

1.

Item	Yearly Demand	Orders Per Year	Order Value	Aug. Inv. Value
1	$ 6,400	4	$1,600	$ 800
2	$ 4,900	4	$1,225	$ 612
3	$ 1,600	4	$ 400	$ 200
	$12,900	12	$3,225	$1,612

2. Order number cannot be increased - minimize inventory

Item	Yearly Demand	Yearly Demand	K	Order Value	Aug. Inv. Value	No. of Orders
1	$6,400	80.0	15.8	$1,264	$632	5.1
2	$4,900	70.0	15.8	$1,106	$553	4.4
3	$1,600	40.0	15.8	$ 632	$316	2.5
					$1,501	12.0

3. Inventory Size cannot be increased - minimize the number of orders

Item	Yearly Demand	Yearly Demand	K	Order Value	Aug. Inv. Value	No. of Orders
1	$6,400	80	16.9	$1,352	$676	4.7
2	$4,900	70	16.9	$1,183	592	4.1
3	$1,600	40	16.9	$ 676	338	2.3
		190			$1,606	11.1

4. Method of Determining Proper Order Quantity

$$Q = K\sqrt{A}$$

Item	Yearly Demand A	$\sqrt{A}$	(N) Orders Per Year	(Q) Order Quantity
1	$6,400	80	4	$1,600
2	$4,900	70	4	$1,225
3	$1,600	40	4	$ 400
		$\Sigma\sqrt{A}=190$	$\Sigma N=12$	$\Sigma Q=3,225$

Order number cannot be increased - minimize inventory

$$K = \frac{\Sigma\sqrt{A}}{\Sigma N} = \frac{190}{12} = 15.8$$

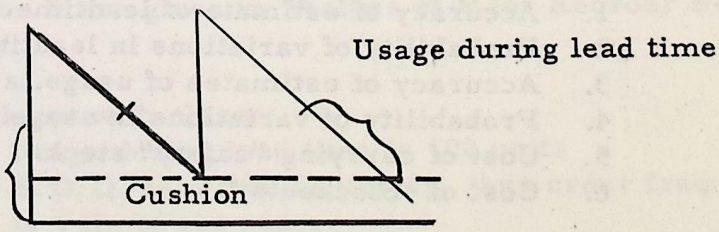
Inventory size cannot be increased - minimize the number of orders

$$K = \frac{\Sigma Q}{\Sigma\sqrt{A}} = \frac{3,225}{190} = 16.9$$

5. INTRODUCTION TO REORDER POINT DETERMINATION:

A. The reorder point is based upon two factors:
   1. Usage during procurement leadtime
   2. Safety stock or "cushion".

B. The reorder point is established at a stock level equal to the usage during the lead time plus the safety stock:



C. Common procedures for determination of reorder point:
   1. Determine usage during lead time and increase by a fixed percentage.
      a. For example: "Multiply usage during lead time by 1.33."
      b. Usually applies same percentage to all items in system.
   2. Determine usage during lead time and add to this quantity usage during a fixed period of time.
      a. For example: "Add 3 weeks usage to usage during lead time to determine reorder point."
      b. Again, usually treat all items in the system the same way.
   3. Reorder when stock gets to a certain level regardless of lead time.
      a. For example: "Reorder when stock level reaches a six month supply."
      b. Common practice in military operations.
   4. Disadvantages of these common procedures:
      a. Consider all items in the system of equal importance
         (1) As much chance of running out of "critical" items as of relative unimportant ones.
         (2) No concern with relative cost of storing certain items.
      b. Usually giving much too much protection to some items and insufficient protection to others.
         (1) Excessive investment in inventory.
         (2) In spite of excessive investment are still not getting adequate protection.

D. Amount of safety stock that will be required to protect a given item will depend upon: (Welch)
   1. Accuracy of estimate of leadtime.
   2. Probability of variations in leadtime.
   3. Accuracy of estimates of usage.
   4. Probability of variations in usage.
   5. Cost of carrying "safety" stock.
   6. Cost of "Stockouts"

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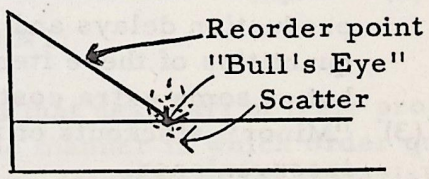
6. SCIENTIFIC REORDER POINT DETERMINATION:

A. Based on many emperical investigations the following reorder point formula has been developed:

$$R = U_L + P\sqrt{U_L}$$

1. Where:
   a. R is the reorder point in units
   b. U_L is usage during leadtime
   c. P is a factor based upon the desired probability of stockouts in terms of once per X years and the order frequency.
2. P is determined on the basis of the properties of the Poisson Distribution.
   a. A mathematical distribution like the normal curve - completely random.
   b. Example firing rifle in vice - hit all around one center spot or bulls eye. - We can predict the variability around the bulls eye.
   c. In a similar manner we can show that the usage parts will vary about the "bulls eye" and can predict this variability in terms of a poisson distribution. Proven by Whitten.



   d. Approach developed by Willson, Bell Lab's 1923 - "Cat and Dog", type of operation.
3. Values for P are given in "Values of P for Reorder Point Formula"
4. Examples:
   a. Work out with class:
      (1) Usage during lead time is 100 units
      (2) E.O.Q. is 2 months supply, thus order frequency is 6 times per year.

(3) Desired probability of stockout is once in 5 years, thus P is 1.3.
(4) Reorder point is 100 plus $1.3\sqrt{100}$ or 113 units.

b. Let class work out:
(1) Lead time equals two months
(2) Monthly usage equals 200 units
(3) E.O.Q. is 4 months supply
(4) Desired probability of stockout is once in seven years. (Ans 132 units)

B. Determination of desired probability of stockout:
1. Common tendency: "Never want to run out of anything ever".
a. This is impossible
b. Usually there are some items which are more important than others.
2. Classification of inventory for safety stock determination.
a. Usually find that stock can be broken down into three categories:
(1) "Critical"-Stockout of these items will cause major production delays and excessive cost. Emergency quantities of these items can't be obtained locally at any cost.
(2) "Major" - Stockout of these items will cause minor production delays and some cost. Emergency quantities of these items may be obtained locally but at some extra cost.
(3) "Minor"-stockouts of these items will cause little inconvenience.
b. To determine probability which should be associated with each of the category definitions, apply groupings such as: 1, 3, 5; or 2, 5, 7; or 3, 7, 10; or 3, 10; Never; to a sample and estimate total investment in safety stock and attendant costs.
(1) Frequently management will establish a desired maximum to be invested in such "protection".
(2) Or the alternatives listed above may be presented and the most desirable selected.

3. In the event that management does not wish to classify the stock (wants same amount of protection on all items), the problem is simplified.
   a. Determine desired investment in protection.
   b. Apply various stockout criteria to a sample, increasing the length of time per stockout until the desired protection investment has been reached.

7. SEQUENCE OF EVENTS SURROUNDING REORDER POINT AND REORDER QUANTITY FOUND IN MANY ACTIVITIES:

A. "Minimum" stocks or reorder points are established by casual evaluation and order quantities in much the same way.
   1. Little consideration of leadtime or safety stock factors.
   2. Stockouts become annoying to the using departments so the "minimums" are raised across the board.
      a. May cut down on stockouts in some areas, but results in needless increase in investment in others.
      b. Overall inventory investment becomes too high and management orders that it be cut down
   3. Rather than cut down on safety stocks, order quantity is decreased and thus order frequency increased.

B. With increased order frequency, probability of stockouts increases and the cycle repeats itself.

8. PROJECT ASSIGNMENT:

A. Inform enrollees that next part of their project assignment is to describe the manner in which order quantities and reorder points are determined for material in the activity which they are analyzing.

B. Handout detailed subject outline.